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# EFFECTS OF HUMAN PERSECUTION ON EUROPEAN RAPTORS

by

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## *Abstract*

Persecution causes population declines only if it adds to the natural mortality and does not merely replace it. Large raptor species with slow breeding rates are less able to withstand heavy losses than are small species with fast breeding rates. Over the last 150 years, persecution has eliminated some of the bigger species from large parts of Europe and is still responsible for restricting the distribution of others. In Britain over this period, the ranges of several species have contracted and expanded again with the rise and partial decline in game preservation, with temporary expansions during two wars when gamekeepers were otherwise employed. Persecution is still restricting the breeding range of the Golden Eagle, the Buzzard, and the Hen Harrier in the British Isles to about half the potential.

In some lists of bounty payments, certain species declined or disappeared in the records during the operation of the scheme, suggesting that the killing itself reduced or exterminated them. But in other lists, no declines in numbers killed occurred over a long period, suggesting that hunters were merely cropping the population and causing no long-term decline. The importance of deliberate killing of raptors is shown by the large proportions of banded birds that were later recovered, and by the proportions of these recovered birds reported as shot. Recovery rates were as high (or higher) for some European raptors as for many game-bird and waterfowl populations exposed to regular hunting seasons. Widespread use of poison on meat baits has had the most damaging effects on European raptor populations, often where the procedure was aimed primarily against wolves or foxes. In recent years, the most commonly used poisons include strychnine, phosdrin, and alpha-chlorolose.

## *Introduction*

In recent years the effects of human persecution on raptors have received much less attention than the effects of toxic chemicals and land-use changes. Yet persecution is still restricting the distribution of several raptor-species in Europe, and in some regions is practised with little less zest than at its peak a century ago. This paper is concerned with the extent of this killing and with its effects on populations, and is aimed particularly at the North American readership. It is not concerned with whether the killing is justified, for this question involves value judgements, which incorporate vested interests and personal preferences.

Large parts of western Europe are privately owned, so control operations are usually carried out, not by government agencies, but by thousands of individual landowners and their "gamekeepers," as well as by the hunters themselves and by stock farmers. Persecution of raptors is widely acknowledged (Bijleveld 1974), but little scientific documentation of its effects is available, partly because most reduction of numbers occurred

between 1850 and 1900, before biologists were interested in recording it. In recent years, too, killing has become illegal in many countries so, practiced subversively, it has proved hard to study. Moreover, in their efforts to understand the birds themselves, biologists have generally avoided working on populations that they knew were being heavily shot.

### *Historical Perspective*

In an attempt to protect domestic stock, the killing of larger raptors was officially encouraged in parts of Europe as early as the sixteenth century by payment of bounties. This seems to have been sporadic, however, and had no marked or long-term effects on populations. It was with the rise in small-game management in the nineteenth century that persecution reached its peak and spread to the smaller species. Game shooting increased in popularity with the introduction of Pheasant (*Phasianus colchicus*) rearing, and again with the improvement in the shotgun, from muzzle loader to breech loader. The objective of total elimination of raptor populations was soon achieved for some species over large areas.

In many countries, the destruction of raptors became an accepted rural practice. No one in his right mind was expected to pass up the chance to kill a hawk. This attitude was reflected not only in the lack of protective legislation but also in the widespread payment of premiums for birds killed and in the employment of gamekeepers with the specific task of destroying predators. In Britain every sizeable estate had at least one keeper, and some idea of their total numbers can be gained from *Castle's Fishing & Allied Trades Directory* (1910) which lists 1,600 registered gamekeepers. This total excludes underkeepers and others concerned with "vermin control." The same attitude persisted well into the twentieth century but, with social and economic changes, increasing education, and the rise of a conservation movement, public opinion is gradually changing. It has so far been reflected in the abolishment of many bounty schemes and in the introduction in one country after another of protective legislation. At the time of writing, fourteen European countries afford full protection to all birds of prey, sixteen afford partial protection (certain species, certain regions, or certain seasons), while one country (Malta) gives no protection (Conder 1977). The species which receive least protection over the Continent as a whole include the Goshawk (*Accipiter gentilis*), Sparrowhawk (*A. nisus*), Marsh Harrier (*Circus aeruginosus*), Buzzard (*Buteo buteo*), and Rough-legged Buzzard (*B. lagopus*), mainly as a result of political pressure from hunters. In some countries, such as Britain and France, legislation is still resisted or largely ignored by the hunting fraternity. Effective law enforcement is difficult on private land.

### *Theoretical Considerations*

It is convenient first to consider the conditions likely to lead to reductions in raptor numbers. The only permanent way to reduce the population of any bird is to reduce its habitat and food supply. The alternative entails holding numbers below the level that the environment will support and removing birds year after year to counter the effects of their breeding.

Whether sustained killing leads to a long-term population decline depends on whether killing replaces the natural mortality, or adds to it. Thus, if the increased mortality from shooting is offset by reduced mortality from natural causes, so that the number of birds which die each year is about the same, the population will not decline. But if the mortality from shooting, or from a combination of shooting and natural causes, exceeds

that which would otherwise occur from natural causes alone, the population will decline. In practice, much depends on when the killing occurs. Its effect is likely to be minimal in the months following breeding, for the population is then at its seasonal peak, with many juveniles that would die anyway or disperse before the next breeding season. In such cases, shooting has to be exceptionally heavy if it is to do more than merely crop an expendable surplus. The effect of killing is greatest if it is done at the start of a breeding season, for the population is then at its seasonal low, after most natural mortality has occurred. Shooting at that time not only adds to the natural mortality, but also concentrates on the breeding adults, the most valuable sector of the population, so that decline is rapid. It was through the annual destruction of breeding pairs that the populations of several species were wiped out over much of Britain before 1900. The traditional nesting places of the birds were well known to the landowners and their keepers, and many Peregrine (*Falco peregrinus*) cliffs in the Scottish Highlands still show the remains of stone shelters, built by the keepers for use as shooting hides. Probably some such shelters are used for this purpose today.

The vulnerability of any raptor also depends on how easily it can be killed. First, some species are fairly tame and easy to shoot; others use conspicuous perches and are easy to catch in leg traps; and yet others eat carrion, so are easy to poison. Throughout Europe, it is the carrion-feeding species that have suffered most because they can be killed in large numbers with minimum effort. Secondly, large species are inevitably more susceptible to the effects of persecution than are small ones. This is partly because large species live at lower densities, but mainly because they have much lower breeding rates and take longer to reach breeding age (Newton 1977). Following a 50% kill, a slow-breeding eagle population could take many years to recover, whereas a fast-breeding Kestrel (*F. tinnunculus*) population could be back in one or two years. In the long-term, therefore, it is the small, fast-breeding species that are most resistant to sustained killing. A third factor influencing vulnerability is the size and distribution of the population to begin with. Any small population which is localised in a restricted habitat is more easily eliminated than a large population that extends into remote country where it is hard to reach. Events over the last 150 years have led to the fragmentation of many formerly widespread populations. Such isolated remnants are vulnerable for another reason—namely, the reduced chance of immigration which might otherwise serve to counter the effects of, say, local persecution.

### *Long-term Trends in British Populations*

These various generalisations can be illustrated by reference to the British raptors, whose history over the last 150 years has been well documented (Witherby et al. 1938, Baxter and Rintoul 1953, Parslow 1967). Early in the twentieth century, five species were apparently eliminated completely for a period as breeders. These species (and their approximate dates of disappearance) were Marsh Harrier (1898), Honey Buzzard (*Pernis apivorus*) (1911), Goshawk (1889), Osprey (*Pandion haliaetus*) (1908), and White-tailed Eagle (*Haliaeetus albicilla*) (1916). The first three had anyway been restricted to small areas by habitat destruction, so that their tiny populations would have been easy to find and eliminate. But the White-tailed Eagle was widespread and probably numbered more than 200 pairs; its extirpation would have been facilitated by carrion feeding (and poisoning) and by a low breeding rate. It is not certain to what extent collectors of skins and eggs were involved in the final demise of these species, but there can be no doubt that it was the gamekeepers who brought them to a low point original-



ly. Only they had the guns, traps, and poison to do it. Four of the species concerned later recolonised from the European mainland and have small populations in Britain at the present time, and the White-tailed Eagle is the subject of a reintroduction scheme (Love et al. 1978).

Several other previously widespread species were much restricted in range, the Buzzard to some western districts, the Hen Harrier (*C. cyaneus*) to the northern and western isles, and the Red Kite (*Milvus milvus*) to a tiny area in central Wales, where game preservation did not take hold (fig. 1). Some people wrote of these species as having "retreated" to remote areas—perhaps from analogy with human behaviour under persecution—but with the birds no retreating was involved. Populations were wiped out from all but remote areas where birds survived in no greater numbers than previously. Under reduced persecution, the Buzzard has since recolonised large parts of the country; the Hen Harrier has reoccupied many mainland areas. The Kite, however, has taken an extremely long time of dedicated protection to reach its 1978 level of 35 pairs. It was hampered by an exceptionally low breeding rate and the continued use of strychnine baits (against crows and foxes) in the breeding areas (Moore 1957, Watson 1977, Davies and Davis 1973, Newton 1972, Sharrock 1976).

The Golden Eagle (*Aquila chrysaetos*) also suffered a considerable diminution in range, and its survival through the worst period, in contrast to the White-tailed Eagle, could be attributed to its occupying some high, inland areas which, at that time, were extremely remote and hard of access. The Peregrine was eliminated from a few areas (e.g., the southern Pennines) but had large reservoir populations on coasts and islands where it could breed free from persecution and produce recruits to offset the losses in other areas. The species least affected were the Merlin (*F. columbarius*), Kestrel, and Sparrowhawk. These were the three smallest, having the best ability to recover year after year from persistent killing.

Summarising, marked reductions in numbers and ranges were associated with low and localised populations at the start, with carrion feeding, with slow breeding rates, or with a combination of these factors. Lesser reductions were associated with large populations living partly away from game preserving areas, little or no carrion feeding, and high breeding rates. The Hen Harrier was the only species with a high breeding rate that was markedly restricted by shooting, but the bulk of the population nested in Red Grouse (*Lagopus l. scoticus*) preserves, and with its fearless nest-defense, the harrier would have been especially easy to shoot at the nest.

Persecution remains a threat to the British raptors and is clearly the main factor restricting the present range of at least the Buzzard, the Hen Harrier, and the Golden Eagle, none of which occupy more than about half their potential range in the British Isles, including Ireland. The Red Kite and others are low because, although perhaps no longer restricted by persecution, they were reduced by it in the first place. Some species are unlikely to achieve their former numbers in the foreseeable future because their habitat is no longer widespread.

### *Effects on Population*

Evidence for the effects of persecution on populations comes from (a) records of numbers killed, (b) correlations between changes in killing and changes in population, (c) recoveries of banded birds, and (d) studies of birds found dead.

(a) *Numbers killed*

The payment of premiums for dead raptors has often meant that good records have been kept of the totals killed. The numbers can be impressive, as the following examples show:

In Norway, 1846–1900, rewards were paid for 223,487 birds of prey, which included 61,157 Golden and White-tailed Eagles up to 1869, dropping to 27,319 eagles in 1870–99 (Johansen 1929). As late as 1963, bounties were paid on 168 eagles.

In the Netherlands, 1852–57, rewards were paid for 219 “eagles,” 12,787 “falcons,” 2,828 “goshawks,” 16,626 “sparrowhawks,” 1,756 “buzzards,” and 5,017 “harriers,” making a total of 39,233 birds of prey, probably largely migrants (Braaksma et al. 1959).

In the Nordrhein-Westfalen districts of Germany, 1951–68, a total of 210,520 raptors; in Lower Saxony, 1959–63, a total of 38,432; in Schleswig-Holstein, 1960–68, a total of 37,793; and at Hessen, 1951–67, a total of 61,353 raptors were killed for reward (Bijleveld 1974).

From a single Scottish estate at Glengarry, in 1837–40, the kills included 98 Peregrines, 78 Merlins, 462 Kestrels, 285 Buzzards, 3 Honey Buzzards, 15 Golden Eagles, 27 White-tailed Eagles, 18 Ospreys, 63 Goshawks, 275 Kites, and 68 harriers, making a total of 1,372 birds of prey (Ritchie 1920).

More recent records from one 1,200-ha hunting preserve in southern England, in 1952–59, list 344 Sparrowhawks (Ash 1960).

Bijleveld (1974) has recently assembled from official statistics totals such as these for many European countries. He estimated that in the 20 years up to 1970 several millions of raptors had been killed on the Continent by game-bird hunters alone, with especially large numbers in France and Germany. The sheer magnitude of such figures has led some people to doubt them, but they are repeated in similar order in region after region, and in each case feet or beak were required as proof of killing. Confusions of species in bounty schemes were probably common, however. The annual figures for particular estates or districts often included many more raptors than could have lived there at one time, a testimony to the effects of movements or to the existence of neighbouring less disturbed populations, from which new recruits continually came.

When culling occurred on migration routes, the totals were often extremely large, but drawn from populations covering a wide area. Each autumn in southwest France, an estimated 30,000 to 50,000 small raptors fall victim in the nets of birdcatchers (people who trap finches to keep in cages), and many others are killed in Pyrenean passes by “pigeon shooters.” Among the ringed raptors reported from the region, 21% came from Scandinavia, 12% from Poland and Russia, 12% from central Europe, 7% from south Germany and Switzerland, 7 % from north Germany, 11% from England, 23% from the Low Countries, and 7% from France (Yeatman, in Bijleveld 1974).

The numbers alone tell us little about the effect of this slaughter on populations, except that in some cases they must have represented at least the bulk of the local stock. Comparing the figures of the present century with those of the previous, the main difference is in the reduced representation of eagles and other large species in many lists, and their complete disappearance from others. That this was in some regions due to the culling itself is suggested by the large initial kills, followed by a swift decline, as the killing continued. For example, at Tenterden in Kent, England, an intensive campaign



for "the thinning out of vermin" began in 1676, and in the next ten years payments were made for 380 Red Kites, after which numbers dropped away rapidly, with annual totals of 35, 13, 2, and 2 (Ticehurst 1920). Likewise, the Scottish Glengarry figures included at least four species which were no longer present a century later, but for which the habitat still seemed suitable (two have since returned). Evidently there have been long periods in recent history when raptor numbers in many European areas were well below what habitats would support.

In other lists, there was no obvious decline in the totals over many years, which suggests that in these areas the hunters were merely cropping the populations concerned and causing no long-term decline. This is indicated in some official statistics from Austria, which show that between 1948 and 1968, premiums were paid annually on about 12,000 to 20,000 birds (table 1). In this and other parts of Europe, the cull by hunters was especially great in the severe winters of 1961-63, when the birds were more than usually vulnerable. Likewise, the 6,000 Goshawks destroyed annually by Finland's 170,000 hunters are thought to be causing no long-term decline in the Goshawk breeding population, for most of these birds are juveniles killed in the few months following breeding (Moilanen 1976, Saurola 1976). Care is needed in using only the records of recent years, however, because in any long-running bounty scheme covering several species, one might expect there to be less change as the years go by, as the larger species are eliminated at an early stage to leave the smaller, more resilient ones.

Table 1. Official Austrian Game Statistics on Birds of Prey Killed Between 1948 and 1968

	Accipiters	Harriers	Buzzards	Total
1948	10,943	386	3,482	14,811
1949	11,406	821	3,757	15,984
1950	13,181	973	5,252	19,406
1951	13,385	674	4,770	18,829
1952	13,533	757	4,152	18,442
1953	13,788	902	5,479	20,169
1954	12,567	695	5,157	18,419
1955	12,024	694	4,757	18,475
1956	12,952	1,068	5,922	19,942
1957	11,967	838	5,071	17,876
1958	11,518	1,033	5,315	17,866
1959	11,886	1,045	5,606	18,537
1960	12,558	908	6,173	19,639
1961	12,983	921	6,825	20,729
1962	13,838	944	7,590	22,372
1963	11,399	911	7,293	19,603
1964	10,755	879	5,872	17,506
1965	7,109	615	4,826	12,550
1966	7,162	695	4,661	12,518
1967	8,922	596	5,292	14,810
1968	9,262	569	5,823	15,654

(From Bijleveld [1974], derived from Oesterreichisches Statisticisches Zentralamt.)

(b) *Changes in persecution and population status*

The evidence is of two kinds: First, the distribution of a species over a wide area fits with variations in persecution. Second, some marked improvement in the status of a species follows a known decline in killing. The Buzzard in Britain provides an example of

both kinds of correlation. In 1800 the species bred throughout the country, but by 1860 it had been eliminated from all but a few western districts, by 1954 it had spread considerably, and by 1970 it had spread even further (fig. 1, Moore 1957, Sharrock 1976). These changes correlate with changes in the intensity of game preserving, helped in later years by a change in attitude. A particularly detailed survey in 1954 showed that the distribution of Buzzards at that time closely mirrored the contemporary distribution of gamekeepers. The bird was commonest in districts where game keepers were scarcest and absent altogether from districts where keepers were numerous (nesting habitat was available throughout).

Further evidence for the influence of gamekeeping on British raptor populations came during the 1914–18 and 1939–45 wars, when many keepers were employed on other things. At these times all raptors (except perhaps the Peregrine during the 1939–45 period) increased and extended their range, and for the commoner species the changes were reflected in the numbers of nestlings ringed each year by amateur bird-ringers (Newton 1972). There was a big increase in the numbers of Sparrowhawks and Merlins ringed within two years of the war's starting and a rapid drop to former levels within two years of the war's ending (fig. 2). The numbers of nestlings ringed must to some extent have reflected the numbers available for ringing, the increase representing the combined effects of improved population and breeding success, under lessened gamekeeping. It was also during this war that the Hen Harrier became properly reestablished on the Scottish mainland, nesting largely undisturbed in the young forestry plantations which had appeared since it was here before. Early naturalists wrote about a similar increase in raptors during the 1914–18 war, but ringing was not sufficiently developed to document it. In both wars increases were not confined to Britain but occurred throughout Europe. Wolves and other mammal predators gained a similar respite and also spread.

More recently, Weir (1978) noted a marked decline in Raven (*Corvus corax*) numbers in part of northern Scotland, associated with the use of poisoned meat baits. In 1964–68, before poisoning started, 16–17 pairs bred in the study area, and 10–11 produced young each year. By 1977, however, when poisoning had been continued for several years, the population was reduced to 5 pairs and 1–2 produced young. Dead Ravens were found in eight of the vacated territories, in some instances together with Golden Eagles.

Where persecution was insufficient to eliminate populations, it sometimes affected their age structure and breeding success, as was apparent among Golden Eagles elsewhere in Scotland. Sandeman (1957) compared the breeding in deer areas, where eagles were not persecuted, with that in grouse and sheep areas, where they were persecuted (table 2). In deer areas, there was no instance of an eagle lacking a mate, but in sheep and grouse areas eight such instances were recorded. In deer areas there was no instance of an adult eagle paired to an immature partner, but in grouse and sheep areas there were four such instances. Both these features were symptoms of excessive killing. An immature partner in a pair meant that either the pair did not lay or that they produced infertile eggs. The mean size of successful broods was the same throughout, but the overall brood size, when pairs that raised no young were taken into account, was 0.6 in deer areas and 0.3 in grouse and sheep areas. In these latter areas, killing was suppressing the breeding output so much that the population could not have been sustained without continued immigration. In populations subjected to even less persecution, the removal of breeding birds does little more than create temporary gaps, which are soon

Table 2. Effects of Human Persecution on Golden Eagles, South Grampians, Scotland 1950-56

	Number of territory years	Territory with only one bird	One member of pair immature	Mean brood- size in successful nests	Mean brood- size in all nests
Deer areas (no persecution)	35	0	0	1.4	0.6
Sheep & Grouse areas (much persecution)	63	8	4	1.4	0.3

(From Sandeman 1957.)

filled by new recruits. Or it may reduce breeding rate, but not enough to cause population decline.

Widespread shooting over decades seems also to have affected the behaviour of individual raptors and their reactions to man, perhaps partly through the selective removal of the tamer individuals. This difference is apparent from comparison of, say, the African populations with the European ones. The African ones generally show themselves more, nest in closer association with man, and allow a much closer approach before taking flight than do their European equivalents. Perhaps the extreme in tameness is found in the Galapagos Hawk (*Buteo galapagoensis*), which will allow observers close enough to read the colour bands (M. P. Harris pers. comm.). Shooting seems also to have affected nest defense behaviour, which is much less vigorous in Europe than in other parts of the world. The difference is especially marked among Goshawks and Peregrines.

### (c) *Band recoveries*

Compared with most other birds, not only are more banded raptors recovered, but very many of the recovered birds are reported as shot or trapped. For the common British species, the percentage of banded birds that were later recovered varied from 7% to 14%, and the proportions of these reported as killed were as high as 68% depending on species (tables 3 and 4). The proportions recovered were greater than those for some waterfowl and game birds exposed to proper hunting seasons and for recognized pest species. Only large waterfowl and Cormorants *Phalacrocorax* showed a higher recovery rate, the former being legally hunted or specially studied, and the latter killed as pests. After 1954, when protective legislation was introduced for raptors, the proportions reported as killed declined (table 4). This decline may have been genuine, or it may have been due to many people's omitting to report the birds they had killed or falsifying the cause of death. In both periods, birds reported as "found dead" may have included some killed by man.

Similar analyses of European recoveries also indicated the importance of persecution in the overall mortality of reported birds (table 5 and 6). They also reflected the regional variations in shooting pressure. Among Kestrels ringed as nestlings in Holland, intentionally killed birds formed 82% of all recoveries from Belgium and France, but only 10% of those from other west European countries. The mean annual mortality calculated from the two sets of recoveries was significantly different, at 59% and 44% (Cavé 1968). In some species, the recoveries implied a difference in wariness between young and old birds or in the extent to which they came near human settlement, for more of

**Table 3. Percentage of Banded Raptors Recovered Compared with Other Birds in the British Banding Scheme**

<i>Raptors</i>		<i>Recognised quarry-species</i>	
Osprey	11	Red Grouse	11
Red Kite	11	Partridge	5
Marsh Harrier	11	Pheasant	7
Hen Harrier	9	Mallard	17
Montagu's Harrier	14	Teal	18
Sparrowhawk	10	Widgeon	16
Buzzard	7	Snipe	5
Golden Eagle	8	Woodcock	8
Kestrel	12	Woodpigeon	10
Merlin	11		
Peregrine	8	<i>Song-birds</i>	
		Resident species	1-4
<i>Owls</i>		Migrant species	<1
Barn Owl	17		
Little Owl	9		
Tawny Owl	9		
Long-eared Owl	7		
<i>Recognized pest-species</i>			
Crow	7		
Magpie	6		
Bullfinch	2		
Cormorant	20		

(From Spencer and Hudson 1977.)

Note: The table excludes swans and geese in which the recovery rates have been inflated by detailed studies; swans are also especially likely to be found after death.

**Table 4. Proportions of British-Banded Raptors Reported as Deliberately Killed Before and After 1954, When Protective Legislation Was Enacted**

	Up to 1954		After 1954	
	Total recovered	Reported as killed	Total recovered	Reported as killed
Hen Harrier	25	20%	148	10%
Montagu's Harrier	19	68%	24	50%
Sparrowhawk	166	60%	71	16%
Buzzard	33	48%	173	14%
Golden Eagle	—	—	18	28%
Kestrel	175	41%	457	10%
Merlin	73	52%	107	16%
Peregrine	16	56%	55	22%

Figures are minima, and it is not known what were the true proportions of recovered birds that were killed. Sparrowhawk and Kestrel to 1969, other species to 1976-77.

the birds recovered in their first year had been shot or trapped than of those recovered in later years. Among Goshawks in Fennoscandia, the figures were 87% and 78% for first-year and older birds, and among Kestrels in Holland they were 34% and 19% (Hoglund 1964, Cavé 1968).

(d) *Studies of carcasses*

Among 35 raptors of various species found dead or disabled in northeast Scotland in 1964–69, 20% had been killed by man (Weir 1971). In a study of Buzzards in the same area, Picozzi and Weir (1976) used a trained dog in regular searches for poisoned baits and for dead birds. They found 52 dead Buzzards in the period 1964–72 and ascertained the cause of death in all but five: 29 (54%) were poisoned, and 9 (15%) were shot or trapped, making a minimum of 69% killed by man. Of the 42 birds aged, 27 (64%) were in their first year. Between 1968 and 1972, the authors found poisoned baits on 12 of 15 estates within 30 km of the study area, together with 28 Buzzard carcasses. In four years before poisoning started on two of these estates, they found 6 adult pairs each spring with 2.3 pairs on average producing fledged young annually. After poisoning started, there were only 4 pairs, with 0.5 pairs producing fledged young annually. The Buzzard was legally “protected” during the period concerned.

**Table 5. Proportions of Raptors Recovered in European Banding Schemes That Were Reported as Killed by Man**

	Country of banding	Total recovered	Reported as killed	Reference
Black Kite	Switzerland	279	80%	Schifferli 1967
Sparrowhawk	Britain	226	48%	Glue 1971
	Denmark	81	71%	Shelde 1960
Goshawk	Finland	532	92%	Haukioja & Haukioja 1970
Buzzard	Fennoscandia	473	62%	Olsson 1958
	Germany		50–80%	Mebis 1964
Kestrel	Britain	632	18%	Glue 1971
	Switzerland and Finland	416	65%	Schifferli 1965
	Netherlands	245	23%	Cavé 1968
Peregrine	Sweden	199	48%	Lindberg 1977
	Finland	46	78%	Mebis 1971
	Germany	107	43%	Mebis 1971

**Table 6. Recoveries of Birds of Prey Banded in Finland**

	Number ringed 1913–62	% recovered	% recovered birds shot or trapped
Goshawk	1,006	27	78
Sparrowhawk	1,724	17	49
Marsh Harrier	208	11	65
Rough-legged Buzzard	164	13	67
Honey Buzzard	242	13	45
Buzzard	803	9	49
Peregrine	195	22	62
Kestrel	2,135	6	53
Osprey	800	4	67

(From Nordstrom 1963.)

These and other surveys show that a high proportion of the deaths of birds that fall into the hands of biologists can be attributed to direct killing by man. Whether they are representative of all deaths depends on how typical a sample was found. One can easily imagine that in the same areas some birds might die in ways in which they would be unlikely to be found (for example, killed and eaten by predators). This means that the role of human persecution in the overall mortality may be exaggerated. Band recoveries suffer from the same drawbacks when used to indicate causes of death; but both methods give useful comparisons with results from other birds and show the prevalence of persecution on sparse, protected populations.

Studies of local populations could not be expected to reflect the general levels of persecution because biologists normally select study areas so as to avoid it. Nonetheless, human interference was the commonest cause of both adult mortality and nest failure recorded in many studies. In some early British work on Sparrowhawks and Merlins, it accounted for every nest over a several-year period (Owen 1916–22, Rowan 1921–22). In more recent work on Sparrowhawks, Buzzards and Kites, it accounted for at least 7%, 8%, and 9%, respectively, of all clutches and for at least 21%, 34%, and 15% of all failures (Newton 1976, Tubbs 1971, Davies & Davis 1973).

### *Methods of Killing*

When the gun is used, birds are often shot at the nest or at any other time they approach within range. In parts of Europe it was common to set out a live Eagle Owl (*Bubo bubo*) and shoot from a hide any raptors or crows that came to mob it; or to wait at concentration points on migration and shoot at the passing birds (Bijleveld 1974). As for traps, the commonest types are leg traps with spring jaws that snap together when the bird steps on a central treadle, holding firm until the bird is removed or dies. They are placed on nests, around carcasses, or on natural or artificial perching places, as in the pole trap. For eagles and other large species in open country, it is usual to build a small mound of stones on which to place the trap. Another type is the cage-trap with two compartments, in one of which live pigeons or other animals are placed to act as decoys; in the other the raptor is caught alive when it steps on a treadle to release the lid. Situated near woodland, such traps are especially effective against accipiters but need daily attention to keep the decoys fed and watered. They are sometimes known as "Swedish Goshawk traps."

Regarding poisoning, raptors are sometimes killed deliberately in this way and sometimes incidentally during attempts to get rid of other animals, such as wolves and foxes. Widespread poisoning alone has caused serious declines, as shown from (a) the coincidence between the periods of poisoning and decline, (b) the finding of corpses at bait, sometimes in numbers large enough to form the bulk of a local stock, and (c) the presence of poisons at lethal levels in tissues. Several cases have been documented in recent years involving local populations of eagles, vultures, and others (Bijleveld 1974, Mendelssohn 1972). One striking instance was the virtual disappearance in recent decades of the once-common Griffon Vulture (*Gyps fulvus*) from Romania and Bulgaria, linked with the widespread use of strychnine for wolf control. In one Romanian area sixty White-tailed Eagles were picked up in one week, and in another area ten Egyptian Vultures (*Neophron percnopterus*) were found dead at a single bait (Bijleveld 1974).

The main poisons used include the traditional strychnine, the more recent organophosphorus pesticide known as phosdrin or mevinphos, and the narcotic alphachloro-lose. Instances of secondary poisoning are known from all these compounds. When used



in eggs, they kill a few raptor species (mainly harriers), but are very effective against corvids, whereas on meat baits they kill very many raptors. The advent of alpha-chloro-lose has led to a great increase in the illegal persecution of British raptors because, compared to other poisons, this material is relatively safe to use. Many instances came to light in 1971–76 from analyses performed by government agricultural departments of carcasses found by amateur naturalists (Brown et al. 1977). Most carcasses were found during March–May each year, which is when gamekeepers and shepherds have a blitz on “vermin.” Different poisons were favoured in different regions, depending partly on local availability.

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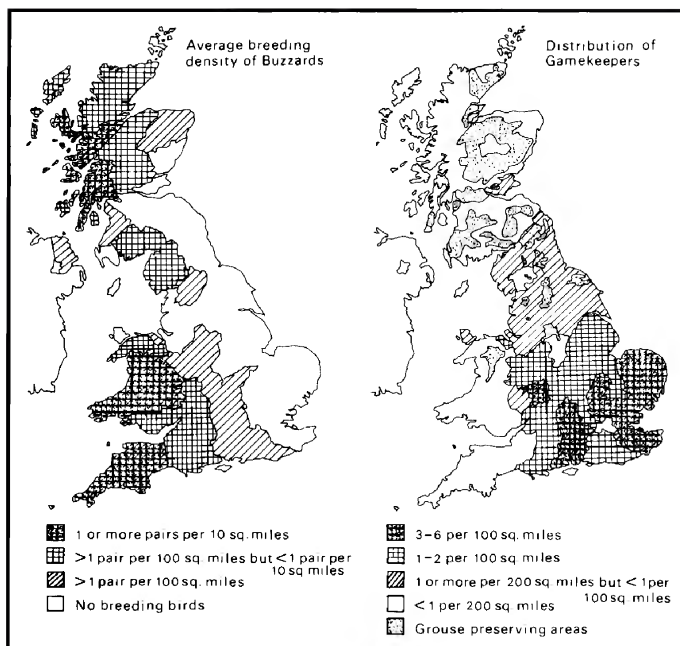


Figure 1.—Distribution of breeding Buzzards in Britain in 1954 (left) compared to the contemporary distribution of gamekeepers (right). From Moore 1957.

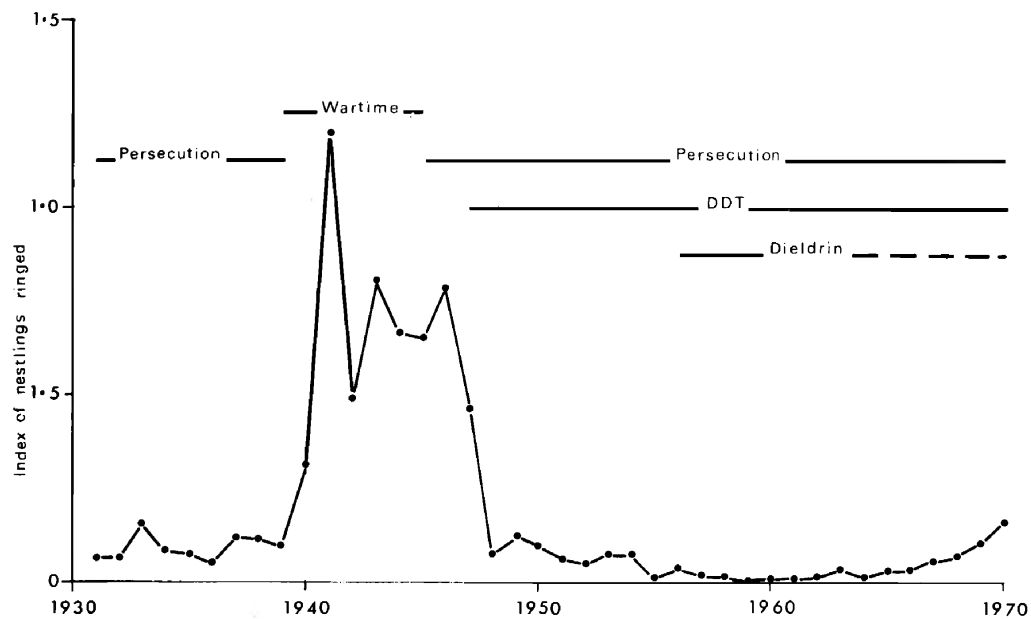


Figure 2.—An index, based on ringing, of the output of young Sparrowhawks in Britain showing the temporary increase during the war, associated with the decline in gamekeeping. The index is the percentage that nestling Sparrowhawks formed of all nestling birds ringed in Britain each year. Re-drawn from Newton 1972.

# MOVEMENTS OF REHABILITATED BALD EAGLES AND PROPOSED SEASONAL MOVEMENT PATTERNS OF BALD EAGLES IN THE PACIFIC NORTHWEST

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## Abstract

Eleven rehabilitated Bald Eagle (*Haliaeetus leucocephalus*) that had been in captivity for various lengths of time were released on the Skagit River in western Washington. They were fitted with colored patagial markers for determining regional movements. Eagles were sighted in both interior and coastal British Columbia and in Puget Sound. A total of 30 reports were received from outside the Skagit Valley. The most distant report was 332 km from the release site, and at least one eagle was still wearing color markers one year after release.

Regional movement patterns of the Bald Eagles in the Pacific Northwest are discussed and a general theory of seasonal movements is proposed for coastal and interior eagle populations of the Northwest. The probable origins of the eagles that winter on the Skagit River and possible migration routes of this population are considered.

## Introduction

Continued pressure on the remaining Bald Eagle population, declared endangered in 1978 in 43 states and threatened in five others by the U.S. Fish and Wildlife Service (1978), emphasizes the need to return to the wild captive and rehabilitated eagles capable of survival. There has been concern that captive and rehabilitated eagles may have little or no chance of survival once returned to the wild because captivity and association with man might make them weak and unfit to compete again with wild eagles. This paper describes the movements of 11 rehabilitated and color-marked Bald Eagles that have returned to the wild. Data on regional movements are interpreted to give an indication of possible migratory patterns of Bald Eagles in the Pacific Northwest in general and of the Bald Eagle population which winters on the Skagit River in particular.

## Methods

Rehabilitation techniques for Bald Eagles prior to release have previously been described in detail (Servheen and English 1976). Eagles were released during January and February of each year from 1975 through 1978. All eagles were released in a Bald Eagle

wintering area on the Skagit River in northwest Washington. This area is currently being managed as a natural area by the Nature Conservancy and the Washington Department of Game. The area offers high food availability during the post-release period and protection from excessive human disturbance.

Released eagles were individually fitted with a patagial marker of Saflag material on each wing between the secondary and tertiary flight feathers. Each marker was fastened with two grommet-type fasteners placed in prepunched holes through four overlapping layers of Saflag material.

Marker colors used were yellow, pink, and orange. Eagles were not individually marked with specific colors or with lettering on the patagial markers. Different colors were used during different years. We found that most observers could not distinguish pink markers from orange at a distance. Eagles were not individually identified on the basis of color marker sightings because of the unreliability of untrained observers and the possible fading of markers.

### *Results and Discussion*

Eleven Bald Eagles have been released on the Skagit River near Rockport, Washington, since 1975 (table 1). All were brought to the Seattle Woodland Park Zoo for treatment of injury or starvation.

Table 1. Bald Eagles Released on the Skagit River, 1975-1978

Date of Release	Estimated Age <sup>1</sup>	Approx. Time in Captivity	Condition When Found	Site of Injury	Approx. Distance from Skagit <sup>2</sup>
01/03/75	3 yrs.	31 mo.	Shot	Wing	Unknown
02/25/75	5 yrs.	2 wk.	Shot	Body	0 km
01/05/76	Adult	49 mo.	Shot	Wing	Unknown
01/05/76	1 yr.	11 mo.	Shot	Wing	120 km
01/05/76	1 yr.	4 mo.	Shot	Wing	120 km
01/05/76	2 yrs.	9 mo.	Shot	Wing	96 km
01/04/77	4 yrs.	21 mo.	Shot	Wing	128 km
01/04/77	3 yrs.	21 mo.	Tendon Damage	Wing	120 km
01/04/77	1 yr.	1.5 mo.	Starving	—	88 km
01/05/78	3 yrs.	6 mo.	Shot	Body	120 km
01/05/78	1 yr.	2 mo.	Shot	Wing	289 km

<sup>1</sup>Age estimate based on plumage characteristics (see Servheen 1975).

<sup>2</sup>Distance from where eagle was originally found to Skagit release site.

*Local Movements.* Immediately after release, eagles spent varying amounts of time at the release site adjusting to the area and their sudden freedom. There was no definite relationship between time in captivity and time spent in the immediate area, although the bird captive for 49 months spent the most time at the release site.

Local movements were limited for the first three to four days by lack of muscle tone that resulted from long periods in captivity in a small flight cage (Servheen and English 1976). As muscle tone and flight ability increased, the eagles began to fly up and down the river and feed with local wintering eagles. Released eagles soon learned the best perching and feeding sites, possibly by observing and following local eagles. Within two weeks of release, activities, perching areas, and movements of released eagles were similar to those of the local wintering eagles. If released eagles had not been marked, it would have been difficult or impossible to distinguish them from wild eagles by their behavior.

*Regional Movements.* Reports of color-marked eagles can be divided into two categories: (1) those from coastal areas in Puget Sound and the Strait of Georgia; and (2) those from interior British Columbia. Thirty reports have been received from areas outside the Skagit Valley. Of these, twenty-three were from coastal areas and seven from the interior (fig. 1). A summary of distances moved by month is shown in figure 2. The most distant report was from Campbell River, British Columbia, on the west side of Vancouver Island, 332 km by air from the Skagit wintering area. No reports were received from locations south of the Skagit River. No color-marked birds were known to have returned to the Skagit in following years; it is possible, however, that they were not recognized as returning individuals because some colors were reused.

Although dispersal movements of rehabilitated and previously captive birds cannot be accepted *per se* to be the same as those of wild eagles, we feel that similar movement pathways would be used by all eagles dispersing from the Skagit area. The validity of the assumption that released and wild birds would have similar dispersal behavior is strengthened by the fact that most released eagles remained with the resident wild population for four to eight weeks and dispersed from the area at the same time as the wild birds. The social nature of wintering Bald Eagles in roosting and group soaring (Southern 1963, 1964; Edwards 1969; Shea 1973; Lish 1975; Servheen 1975; Stalmaster 1976; Steenhof 1976; Sherrod et al. 1976) suggests that movement patterns may be learned by inexperienced individuals partially by visual observations of other eagles and by participation in group activities. The existence of socially facilitated learning of movements in Bald Eagles would indicate that both released and resident eagles would tend to move in similar patterns and, thus, this extrapolation is valid.

The distribution of reports by month (table 2) shows that few sightings occurred from June through December. Several possible explanations exist for this lack of sightings: (1) most patagial markers do not remain intact for more than six to eight months; (2) eagles move into more remote northern British Columbia at this time; or (3) the color-marked eagles are not surviving more than six to eight months in the wild. The last explanation is unlikely as the critical period for survival would probably be the first few weeks after release because of their initial inability to fly well and compete successfully with wild eagles (Servheen and English 1976). The first explanation is possible although we do have one report of a color-marked eagle on the Nicola River on 11 January. This bird had to have been wearing patagial markers for at least one year, but it is conceivable that markers are not staying on every eagle.

**Table 2. Reports of Color-marked Bald Eagles More Than 9.5 Kilometers from the Release Site by Month of Occurrence**

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Total number of sightings <sup>1</sup>	4	4	15	2	6	1	2	3	0	0	0	0
Selected sightings <sup>2</sup>	4	4	11	2	3	1	2	2	0	0	0	0

<sup>1</sup>Includes sightings from within Skagit Valley but no sightings within 9.5 km of the release site. Probable resightings of same individuals are included. N = 37.

<sup>2</sup>Probable resightings of same individual at same location eliminated. N = 29.



The possibility that color-marked eagles are moving with much of the rest of the population into more northern remote areas where observers are few seems the most plausible explanation at this time. From Alaska to Washington, movement patterns of coastal Bald Eagles are probably keyed to time of spawning of Pacific salmon (*Oncorhynchus* spp.), the most abundant food resource from August through December. In general, salmon runs occur earliest in northern coastal areas of Alaska and latest in southern coastal areas of Puget Sound. The two most distant reports, from Campbell River and Kamloops Lake, both occurred in August. Beebe (1974) theorized that Puget Sound eagles move north in August to utilize early morning salmon runs (fig. 3) and then follow the runs southward, arriving in Puget Sound in November and December (fig. 4).

Eagle counts on the Skagit (Servheen 1975) and in the southern Gulf Islands, just north of the San Juan Islands (Hancock 1964), show that adults arrive in November and December while subadults do not arrive until mid to late January. If eagles are returning south to Puget Sound in November and December, we would expect some sightings of color-marked birds during this time. The lack of reports may be because adults are the first eagles to return south during this time. Since only one of the eleven eagles color-marked was an adult, this may explain the lack of November-December sightings.

Adults are first to arrive in winter in numbers in Puget Sound, possibly because they do not move as far north during the fall as subadults. This theory assumes that most adults seen in the Puget Sound-Gulf Islands area in winter are adults from the local population. Hancock (1964) lends support to this by saying, "Not only were the first birds to arrive (in the Gulf Islands) adults, but these adults in many cases appeared paired and were located in the vicinity of nest sites." Sherrod et al. (1976) state that adult eagles in the Aleutian Islands are less prone to wander than subadults. Similar attachment to the nesting site during the winter is noted by Hensel and Troyer (1964) on Kodiak National Wildlife Refuge, where most nest sites were defended by resident adults even after the young fledged. Thus, it seems possible that adult eagles nesting in coastal areas from the Aleutian Islands south to Puget Sound wander locally in the winter, but their movements are more limited than those of subadults. Adult eagles in Puget Sound tend to move north after the nesting season, but probably not as far as subadults. Adults return to their nesting areas in midwinter before subadults.

The movements and aggregations of wintering Bald Eagles are determined by food availability. Most subadults from Puget Sound probably move north with adults after leaving the nest to utilize early northern salmon runs. Sherrod et al. (1976) suggest that in the Aleutians adults rely less on carrion than subadults, and adults tend to utilize available food sources near nest sites during much of the winter, usually by catching live prey, whereas subadults depend mostly on carrion in areas away from nest sites. This results in a form of food resource partitioning which is maintained by some territorial defense around nest sites by resident adults even during the nonbreeding season. We propose a similar system of modified resource partitioning could exist between adult and subadult Bald Eagles throughout the coastal areas of the Pacific Northwest. Overlap of food resource utilization between adults and subadults can be expected at sites of excessive food concentration such as salmon spawning areas. Subadults are dependent on food concentration areas throughout most of the winter. Adults also utilize food concentrations, but for shorter periods. Many coastal adults move to breeding areas in mid to late winter where they catch live prey and use small local carrion concentrations. Territorial exclusion of other eagles by resident adults probably becomes more active as the nesting

season approaches, and subadults disperse from dwindling food concentrations. This resource partitioning is well adapted to the Pacific Northwest coast where weather conditions do not preclude winter food availability around nest sites and where a multitude of food concentrations exist at salmon spawning areas. Bald Eagles in interior North America face a different food resource distribution in winter, and such a modified food resource partitioning system probably does not and cannot exist in the interior.

*Possible origins of the Skagit Wintering Population.* Of the eleven eagles released to date, nine remained in the wintering area within 9.5 km of the release site for at least 45 days. They stayed in this area with the resident wintering birds until the food supply of dead salmon was depleted. With depletion of the food supply, the released eagles dispersed from the area with the local wintering population.

If the dispersal of color-marked eagles released on the Skagit is indicative of dispersal movements of the wild population, the Skagit eagles originate in both interior British Columbia and in coastal areas in Puget Sound and the Strait of Georgia (fig. 4). Adult eagles arrive on the Skagit (Servheen 1975) at the same time as adults at nesting sites in the Gulf Islands, British Columbia (Hancock 1964). No data are available on whether most coastal nesting territories have adults present in them during winter although adult eagles are certainly present in the general area throughout the winter. Grubb et al. (1976) found a total of 44 active nests in the San Juan Islands. If the resident adults are wintering around their nests, we would expect 80 to 90 adult Bald Eagles in the San Juans through the winter. On the other hand, if resident adults move locally in winter in response to local food concentrations, some of the San Juan adults could be on the Skagit.

Substantial numbers of Bald Eagles winter on lakes in southern British Columbia eating American Coots (*Fulica americana*) (Brooks 1922, Munro 1938). Many eagles also follow salmon runs far inland up the Fraser River (Beebe 1974). The interrelationships between coastal wintering populations and inland populations are probably complex. Eagles inhabiting inland areas in British Columbia are forced south and west during winter as lakes and rivers freeze (fig. 3). It is likely that most eagles wintering on southern British Columbia lakes are more northern birds that have been pushed south, but no banding data are yet available to confirm this likelihood. Eagles wintering on inland rivers of the Fraser system are probably mixtures of inland birds driven south and west and coastal birds moving upriver to utilize inland salmon runs (fig. 4). The Skagit probably falls into the category of a mixed inland and coastal population, and dispersal movements of color-marked eagles (fig. 1) seem to support this.

We propose that there are two general migration routes for the Skagit wintering population (fig. 5). The first route is over the mountains in a north and northeast direction toward interior British Columbia. The second route is down the Skagit Valley to the west, then north through Puget Sound and the Strait of Georgia.

There is ample evidence for the second route down the Skagit Valley to the west. We have 23 reports of color-marked eagles along the Skagit between Rockport and Puget Sound, and there are 18 reports of color-marked eagles in the San Juan Islands.

There is no direct evidence of the first route over the mountains other than six reports of color-marked eagles in British Columbia. Indirect evidence of such a high-altitude overland route is available, however. Wintering eagles on the Skagit River often soar in groups and ascend to several hundred meters above the valley floor (Servheen 1975, 1976). Soaring behavior among groups of wintering Bald Eagles has been reported in

other areas (Southern 1964, Grewe 1966, Edwards 1969, Jonen 1973, Lish 1975, Steenhof 1976, Platt 1976, Stalmaster 1976, Sherrod et al. 1976) and has often been attributed to preroosting behavior, pair-bond maintenance, food resource "signalling," or play. Vertical soaring in the Skagit may also be a means of using rising thermal air formations to gain altitude necessary to cross the rugged mountains to the north. Migrating eagles could use mountain ridgelines for lift and as travel routes for long distances. Such travel over mountains could provide rapid movement between drainages such as the Skagit and the Nooksack, relatively close together but separated by precipitous mountains. Large variances in daily counts on the Skagit (Servheen 1975) and the Nooksack (Stalmaster 1976) may be evidence of such rapid, high-altitude travel. High-altitude travel is not uncommon in other birds, and flights over mountains at altitudes of 6000 meters have been reported (Meinertzhagen 1955, Berger and Hart 1974). The social nature of soaring flights indicates that eagles may fly over mountainous terrain in groups like several other raptor species (Brown and Amadon 1968). Such group movements would be advantageous to first-year birds who could learn routes and of special advantage (Ward and Zahavi 1973) to subadults which are primarily dependent on randomly distributed but concentrated food sources during winter.

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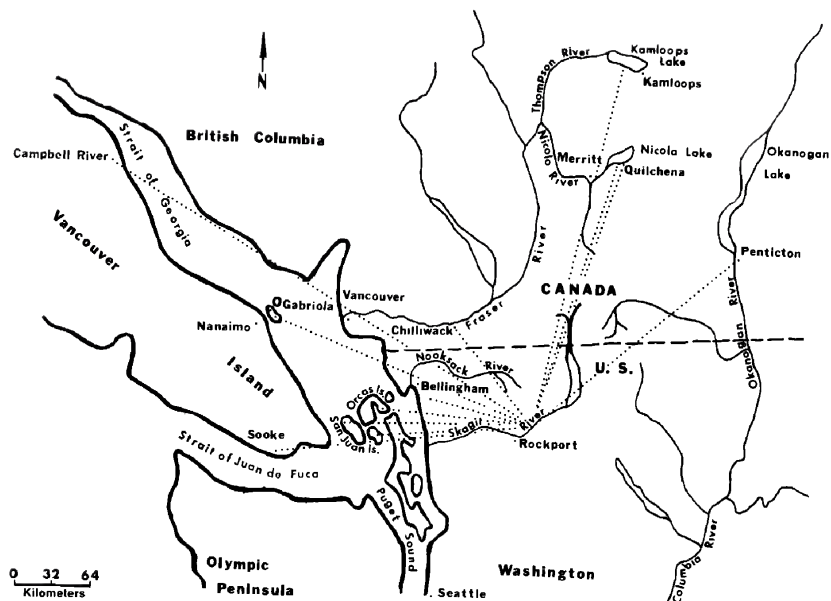


Figure 1. Sighting locations of color-marked Bald Eagles released on the Skagit River, 1975 through 1978. (Multiple sightings at individual sites not indicated.)

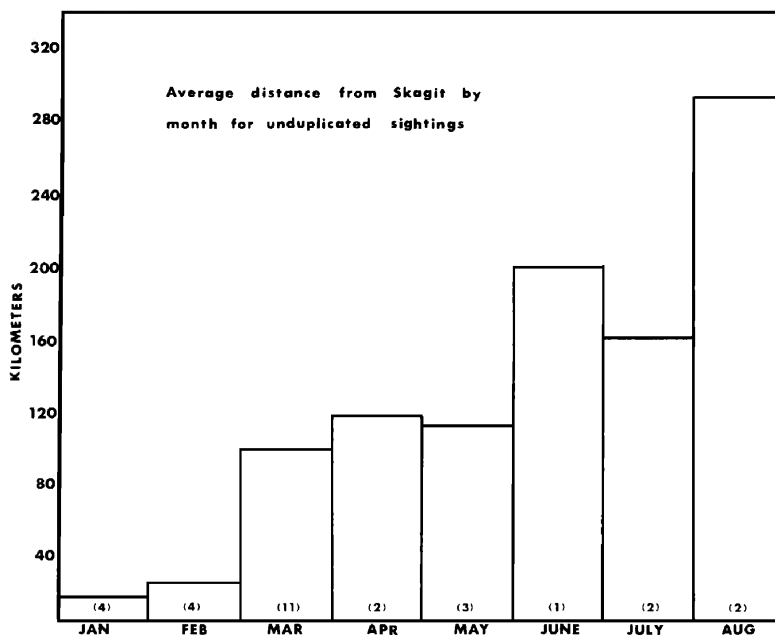


Figure 2. Average distance from Skagit release site by month for unduplicated sightings. No sightings included from within 9.5 kilometers of release site. Number of sightings per month in parentheses. N = 29.

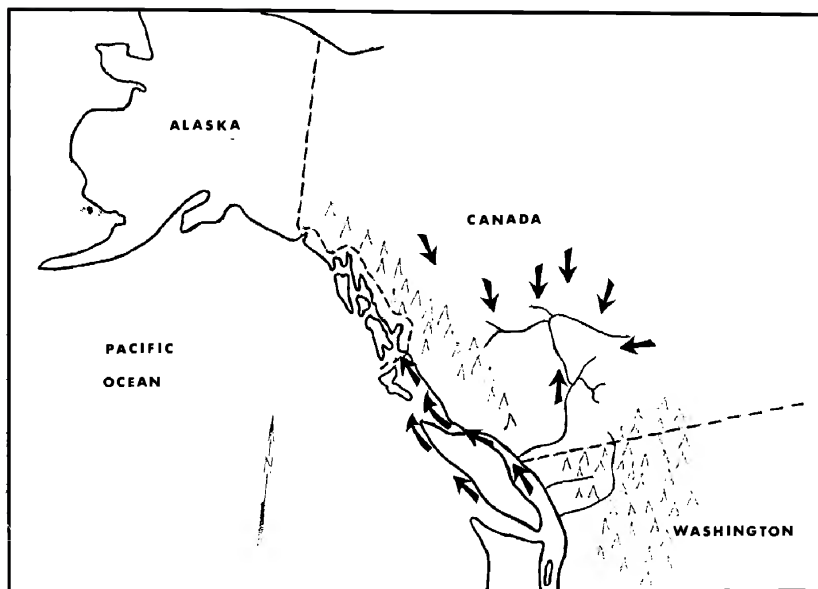


Figure 3. Hypothetical movement patterns of Bald Eagles during August and September in the Pacific Northwest.

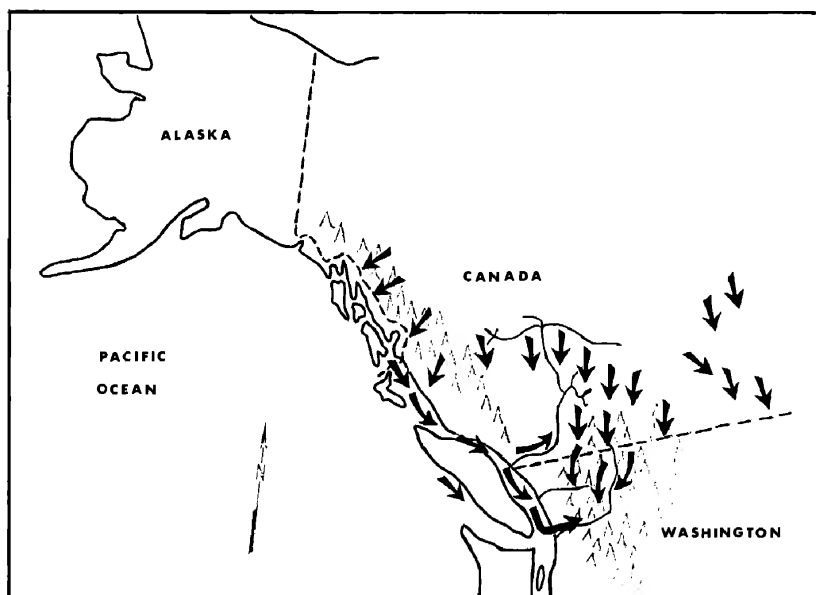


Figure 4. Hypothetical movement patterns of Bald Eagles during October, November, and December in the Pacific Northwest.



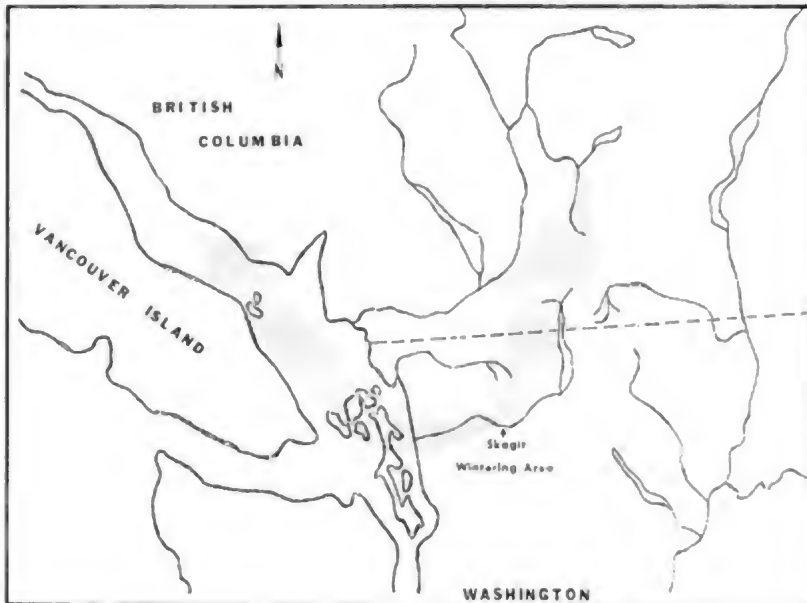


Figure 5. Hypothetical dispersal routes for Bald Eagles wintering on the Skagit River, Washington.

## SNOW GOOSE TAKEN BY PEREGRINE FALCON

by  
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While working with four companions near Rathbun Reservoir in south central Iowa on 1 October 1975, I heard geese calling and saw two large birds, presumably geese, flying in a rather erratic manner approximately 150 m above the ground and perhaps 0.4 km from our position. At that moment, a member of our party located the main flock, and everyone watched as 20 Snow Geese (*Chen caerulescens*) passed directly overhead. As I turned to relocate the two birds I had been watching, I saw an unidentifiable mass of wings and bodies tumbling rapidly toward the ground. At approximately 30 m above the ground, the tumbling ceased abruptly, and we observed a falcon, with cupped wings, struggling to support a weakly flopping goose. The raptor had a single talon fastened in the abdomen of the goose but seemed unable to support the weight of its prey. The pair continued down almost vertically and hit a low, brush-covered hill less than 200 m from our position. A similar aerial tumbling sequence involving a Peregrine Falcon (*Falco peregrinus*) and a crow (presumably *Corvus brachyrhynchos*) was reported by Hager (Bent 1938).

Within a few seconds, the falcon reappeared and began to leisurely circle the area. Almost immediately it was surrounded by 1,500–2,000 blackbirds of unidentified species which were staging in the area. At times the falcon was completely engulfed in a swirling mass of blackbirds; however, it did not seem alarmed or even concerned. Occasionally the falcon would make a sudden change in its flight path, and the blackbirds would scatter only to reform in a flock surrounding the raptor. Falcons are not immune to attacks by other birds. Tufts (1973) reported bird census-takers in Nova Scotia saw a Peregrine being mobbed by about 60 Red-winged Blackbirds (*Agelaius phoeniceus*).

Our falcon made no attempt to return to its prey and eventually left the area. During this spectacular aerial display, the raptor approached our position several times enabling us to see the facial markings and brown-streaked breast we identified as those of an immature Peregrine. It is unlikely we misidentified the falcon since it did not seem large enough to be a Gyrfalcon (*Falco rusticolus*), did not have the black axillars of a Prairie Falcon (*Falco mexicanus*), and was considerably out of the normal range for both of these species.

A few minutes after the falcon left the area, we located an injured juvenile Snow Goose (blue phase) near the point of impact. The goose was unable to fly; muscle tissue was torn from the left leg, and several puncture wounds were observed in the abdominal and lower breast region (fig. 1).

Several authors have reported Peregrines taking large prey. Bent (1938) listed Ring-necked Pheasants (*Phasianus colchicus*) and ducks up to the size of Mallards (*Anas platyrhynchos*). Cade (1960) reported Brant (*Branta bernicla*) in Alaskan Peregrine nests. In Britain, Witherby et al. (1939) listed Brant, Barnacle Goose (*Branta leucopsis*), Shelduck (*Tadorna tadorna*), and Great Black-backed Gull (*Larus marinus*). Eurasian records (Utendörfer et al., 1952) list Greylag Goose (*Anser anser*), and Red-breasted Goose (*Branta ruficollis*).

Hayes (1976) reported his trained Prairie Falcon (which is similar in size to a Peregrine) took several Canada Geese (*Branta canadensis*) before its shoulder was broken by the mate of a goose it was holding. Steve Sherrod (pers. comm.) related a number of recent accounts of trained falcons pursuing and attacking geese. The following is Sherrod's personal account of one of these incidents. "In December 1970, I flushed a pair of Snow Geese (one blue and one white phase) from a pond inadvertently as I approached another pond covered with ducks. My Peregrine stooped and knocked the blue phase down in the water. After circling several times and being unable to grab the goose in the water, she then flew after the white phase and knocked it down on land. The goose assumed the threat posture with wings out and arched neck, hissing, as the falcon stooped back and forth hitting it in the head. Finally the falcon bound to the head of the goose sidewise so that the extended wing of the falcon was at right angles to the wings of the goose. When I arrived, the left humerus of the falcon was broken although the bird clung to the head of the goose. The powerful wing flapping of the captured goose had apparently caused the injury." Sherrod concluded that Peregrine Falcons are marginally capable of killing geese, and there is a great possibility for injury to the falcon either directly in the associated battle or indirectly from mobbing by conspecific flock members.

While trained Peregrines (and presumably wild Peregrines as well) are capable of taking geese, I am not aware of a record in the literature where a wild Peregrine was actually observed taking a Snow Goose.

I am indebted to S. Sherrod, G. Crim, and L. Crim for their review of this paper.

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## BODY WATER OF THE AMERICAN KESTREL

by

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### Abstract

Body water mass was measured in 25 American Kestrels. I examined the potential of estimating body water mass from field measurements of wing chord length and body weight. Wing length was not a useful predictor of body water. The body water of kestrels collected in April, July, and September could be estimated with an accuracy of  $\pm 4.0\%$  by multiplying their body weights by 0.6104, 0.6455, and 0.6143, respectively. This method can be applied very easily in the field.

In one phase of a major study I investigated how accurately the weight of body water of American Kestrels (*Falco sparverius*) can be estimated from measures of body weight and wing length. The more comprehensive study was designed to measure the energy metabolism of kestrels in the field using the variables in the equation used to estimate  $\text{CO}_2$  production based on turnover rates of  $\text{D}_2\text{O}$  and  $\text{H}_2^{18}\text{O}$  (see LeFebvre 1964 and Mullen 1970 a and b and 1973). Body water is one of the variables in the equation used to estimate  $\text{CO}_2$  production based on turnover rates of these heavy isotopes of water. The accuracy of such estimates of  $\text{CO}_2$  production is closely tied to that of body water, e.g., a 5% error in estimating body water causes an error of the same magnitude in estimates of energy metabolism. I therefore began a search for the most accurate method of estimating body water that could be implemented in the field without sacrificing the bird.

The literature suggests that the fat-free body weight of a kestrel could be used to estimate its body water. Studies by Odum et al. (1964), Child (1969), Child and Marshall (1970), and Zimmerman (1965) have indicated that the ratio of body water to fat-free body weight in migrant birds is virtually a constant, little affected by the degree of fatness, stage of migration, sex, season, species, or wing length. On the other hand, Masher and Marcstrom (1976) reported a weak correlation between the ratio of water to fat-free body weight and wing length in Dunlins (*Calidris a. alpina*) during autumn migration.

Fat-free body weight cannot be measured without sacrificing the bird. Several investigators, however, have shown that fat-free body weight is highly correlated with wing length, an easy measurement to make in the field. But this method of estimating fat-free body weight should be used with some caution since the relationship between these two variables changes seasonally, e.g., Savannah Sparrow (*Passerculus sandwichensis*), Connell et al (1960); House Sparrow (*Passer domesticus bactrianus*), Dolnik (1970); Dunlin, Masher and Marcstrom (1976); and wood warblers (*Dendroica* sp.), Rogers and Odum (1964). Additionally, Moreau and Dolp (1970) and Snow and Snow (1963) found no or very weak correlations between wing length and fat-free dry weights in passerines.

In this study I examined the potentials for estimating the body water content of kestrels by two methods. The first involved estimating the fat-free body weight of an indi-

vidual from its wing length and multiplying this value by the ratios of mean body water weight: fat-free body weight measured on a small sample of individuals in the population. In the second, the body weight of an individual was multiplied by the mean of the body water weight: body weight ratio which was based on a sampling of individuals in the population.

### Methods

Sixteen male and nine female kestrels (23 adults, 2 immatures) were trapped in bal-chatri traps in Cache County, Utah, in April, July, September, and November of 1973 and 1974. Birds were transported to the laboratory at Utah State University, weighed to the nearest 0.1 g, and their wing chord lengths<sup>1</sup> measured to the nearest 1 mm. Each was then killed in an atmosphere of N<sub>2</sub>, frozen, and stored. Later each carcass was vacuum dried for a minimum of 3 days to constant weight. To facilitate drying, the body cavity was opened, and the pectoral muscles were macerated. The weight of body water was considered equal to the body weight at capture minus the vacuum-dried weight. Each carcass was chopped into small pieces and the fat extracted in Soxhlet apparatus, using petroleum ether (B.P. 60–80°C) as the solvent, and dried to constant weight in a hot-air oven at 80°C. The weight of body fat was equated with the vacuum-dried weight minus the dry weight of the fat-extracted carcass (i.e., the fat-free dry weight). The fat-free body weight equals the weight of the bird just before death minus the weight of body fat. Student's test was used to compare any two means. Statistical significance was accepted at the 0.01 level of probability.

### Results

*Wing length and fat-free weight.* Wing lengths of the kestrels were correlated with neither their fat-free body weight nor their fat-free dry weight. The correlation analysis was performed on the data grouped according to the month of capture and on the combined data for all individuals.

*Body water: fat-free weight ratio.* The body water: fat-free weight ratios for birds collected in April, July, September, and November averaged .6426, .6676, .6533, and .6412, respectively (table 1). The ratios for April and November were not significantly different ( $P < .01$ ), but both differed significantly from the ratios in July and September. The ratio for birds captured in July differed significantly from that of those captured in September. There were no apparent differences in these ratios between the sexes for July, September, and November, but this conclusion is based on very small sample sizes collected in July and November. The sample size for April is also quite small, but the data suggest that the ratio differed between the sexes for that month.

*Body water: body weight ratio.* The ratio of body water to body weight was inversely related to weight of body fat in males and females (fig. 2). In females the ratio decreased from 0.66 to 0.55 as weight of body fat increased from 3 to 22 g. The relationship between body fat and the ratio of body water to body weight was not significantly ( $P < .05$ ) different between sexes. The body water: body weight ratios for kestrels collected in April, July, September, and November averaged .6100, .6455, .6142, and .5752.

### Discussion

*Body water: body weight ratio.* The body water of the kestrels collected in April, July, and September could be estimated with an accuracy of  $\pm 4.0\%$  by multiplying their body weights by 0.6100, 0.6455, and 0.6142, respectively. This method can be

Table 1. Body weight, water, fat, and body water: fat-free weight ratios of American Kestrels collected in 4 different seasons.

Month of Collection	Sample	Mean Body weight (g)	Mean Body water (g)	Mean Body water Fat-free wt.	Mean Body weight	Mean Body fat (g)
April	4 ♂ ♂	98.2	59.8	.6365	.6090	4.29
	1 ♂	136.0	83.7	.6539	.6160	8.03
July	3 ♂ ♂	103.4	66.4	.6636	.6426	3.38
	2 ♀ ♀	109.8	71.3	.6707	.6498	3.44
September	8 ♂ ♂	106.6	65.8	.6676	.6455	5.70
	5 ♀ ♀	119.1	72.2	.6528	.6185	8.33
November	1 ♂	96.6	58.7	.6533	.6142	4.69
	1 ♀	145.1	78.8	.6385	.6074	22.48
				.6426	.5430	
				$\bar{x} = .6412$	$\bar{x} = .5752$	

 $\bar{x}$  = mean for both sexes



applied very easily in the field and is sufficiently accurate to be used with the  $D_2^{18}O$  method to estimate the energy metabolism of a kestrel in the field.

*Wing length and fat-free body weight.* The lack of any correlation between wing length and fat-free body weight in a given season is somewhat puzzling. Individuals collected in September may have been migrants representing populations with different geographical origins, but this should not have been true in July. My results show that wing length cannot be used to predict fat-free weight of the American Kestrel and, therefore, cannot be used as a first step in estimating body water.

*Body water: fat-free weight ratio.* The water content of kestrels expressed as a fraction of fat-free weight is lower than that reported for passerines and shorebirds, which seem to be the only avian groups for which comparative values are available. The ratios of water: fat-free weight reported by Child (1969) for Swainson's Thrushes (*Hylocichla ustulata*) ranged from .6839 to .7029, while the mean values for 10 other small arboreal birds ranged from .6700 to .6967 (Child and Marshall 1970), leading them to suggest that in practice a water ratio of  $.6870 \pm 0.011$  could be used for other species of adult migrant birds ranging in size from the Yellow-billed Cuckoo (*Coccyzus americanus*) to small warblers (*Dendroica* sp.). I computed the water content for Dickcissels *Spiza americana* collected in winter, during migration and during the breeding season from the data in Zimmerman (1965). The mean values ranged from .6774 to .7086 and did not vary seasonally. The water content of Dunlins ranged from .66 to .71 (Mascher and Marcstrom 1976).

In contrast, the mean ratios of water: fat-free weight of kestrels in this study ranged seasonally from .6412 to .6676. These values are significantly lower and do not overlap with those cited above for passerines and shore birds. Data on the water content of other species are not available, and the question of whether these low values are characteristic of Falconiformes, or raptors in general, can be resolved only by future investigations.

The seasonal changes in the water content of the kestrel resemble the pattern in Chaffinches (*Fringilla c. coelebs*) (Gavrilov and Dolnik 1974). The highest water content of the year in Chaffinches is reached in July, following the breeding season, while body fat is at its lowest level.

### Summary

1. Body water: body weight ratio and wing length were evaluated as independent predictors of the body water of the kestrel.

The body water of kestrels collected in April, July, and September could be estimated with an accuracy of  $\pm 4.0\%$  by multiplying their body weights by the body water: body weight ratios 0.6104, 0.6455, and 0.6143, respectively. This method can be applied very easily in the field.

Wing length of kestrels was not correlated with fat-free body weights, body mass, or body water.

2. Body water: body weight ratios in kestrels ranged from 0.65 to 0.55.

In both males and females the ratio was inversely and nonlinearly related to body fat values that ranged from 3 to 11 g. In the range of 11 to 22 g of body fat, the relationship appears to be linear. The latter data are for females only.

3. Mean water content of kestrels expressed as a fraction of fat-free body weight ranged seasonally from 0.6142 to 0.6612 but was relatively constant within a season ir-

respective of sex, size, or fat accumulation. The water-content values were significantly lower than those reported for passerines and shorebirds.

### Acknowledgments

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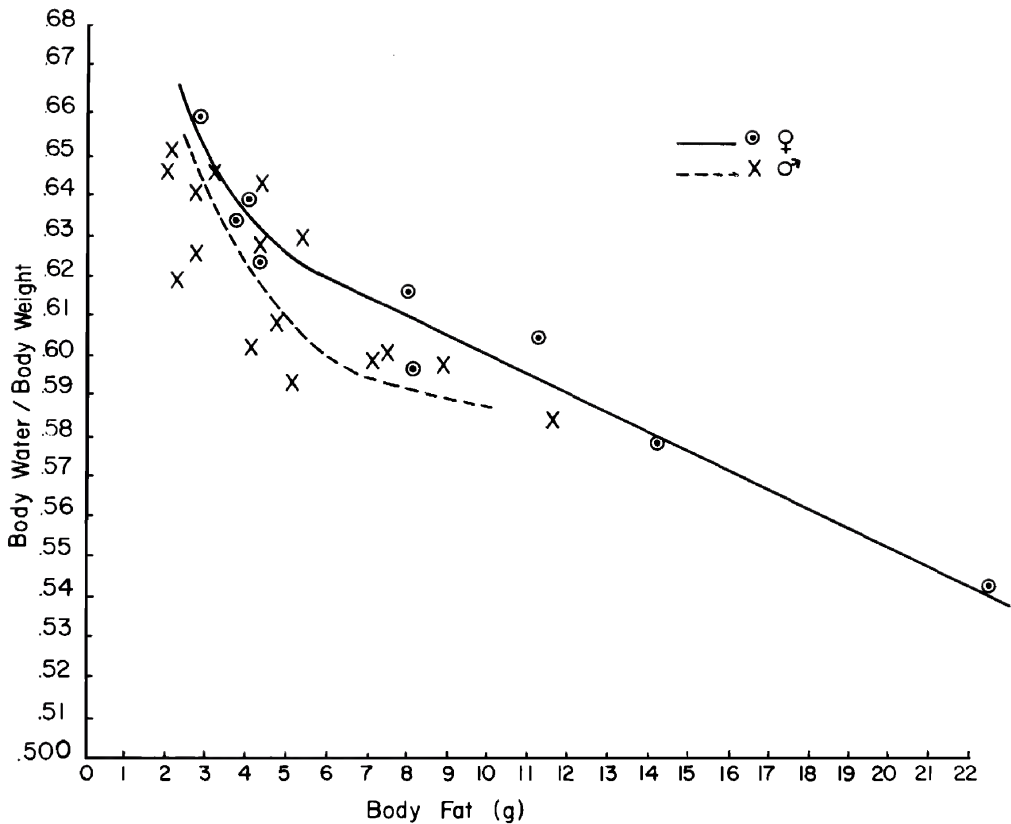


Figure 1.—The relationship between body fat and the body water: body weight ratios of kestrels.

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